CSS Long Term Control Plan Update

Basis for Cost Opinions

City of Alexandria
Department of Transportation and Environmental Quality

FINAL – October 2015

GREELEY AND HANSEN

Table of Contents

Table of Contents

List of Tables

List of Figures

Section 1 Introduction

In order to compare alternatives, cost opinions, which include construction, capital and operating and maintenance (O&M) costs, will be prepared for each proposed alternative. This report provides the basis for those cost opinions. These costs are conceptual and will be used to provide an order of magnitude cost; more detailed cost estimates will be developed later in the LTCPU process when necessary. Cost estimates will be developed for the different strategies and technologies associated with stormwater, sanitary and combined flow. The various technologies are briefly introduced here, but are further defined and evaluated in the subsequent technical memoranda:

- CSO Technology Screening; and
- Alternatives Development.

The costs used in this memorandum range from the present year to several years ago. Older costs were escalated to present costs using the Engineering News-Record Construction Cost Indices (CCI). To calculate present costs the following equation was used to calculate 2014 costs based on a current CCI of 9846 (August 2014):

$$Original\ Cost * \frac{Current\ CCI}{Original\ CCI} = Current\ Cost$$

All costs are in 2014 dollars unless noted otherwise.

The cost opinions included in this report are for initial screening and alternative development purposes only. Since the different alternatives have minimal detailed design data, the prepared cost estimates should only be considered concept level estimates. Once the different alternatives have been further developed and designed, the cost estimates presented in the reports may require significant adjustments to accurately reflect the site specific conditions which apply to each alternative.
Construction costs will generally include a 35% contingency. Project costs will be included at 35% of construction costs and include planning, design, construction management, administration, permitting, and easements.

1.1 Accuracy and Range

The accuracy of an estimate varies depending on the methods used, the amount of project information available, and the time available to prepare the estimate. Using these criteria, the Association for the Advancement of Cost Engineering (AACE) classifies estimates into five types based on the level of detail and information available. The status of the alternatives in the LTCPU alternatives evaluations is such that the cost estimates are Class 4 estimates. The accuracy range for Class 4 estimates is -30% to +50%.

Section 2 Stormwater Flow

2.1 Green Infrastructure

Unit costs for the implementation of each of the Green Infrastructure (GI) technologies are based on reviews of local, regional, and national sources of data to determine reasonable cost ranges for implementing the selected GI practices. Due to the urban nature of the combined sewer area and the associated complications that are likely to occur (including issues such as existing infrastructure and utilities, limited construction access, and smaller project footprints), it was generally assumed that implementation costs would be at the higher end of documented construction costs. It was also assumed that most, if not all, of the GI work would be in the form of retrofits (as opposed to new construction) which also adds considerably to project costs as a result of the above-mentioned constraints.

2.1.1 Bioretention

Bioretention facilities can be known by many names, including bioretention basins, bioretention filters, or rain gardens, among others. These names are sometimes based on the size (with rain gardens typically referring to smaller scale facilities) and/or functionality (without or without underdrains), but all act in the same manner. Bioretention refers to the utilization of soils and plants to remove pollutants from stormwater runoff. This runoff is eventually conveyed to a treatment area which can consist of a grass buffer strip, sand bed, ponding area, mulch layer, an engineered soil media consisting of sand, soil and organic matter and plants capable of resisting inundation periods followed by dry periods.

In a 2012 technical memorandum produced by DC Water titled *Technical Memorandum No. 6: Green Infrastructure Technologies*, estimated that residential BMPs have a cost between $5 and $12 per square foot. Larger scale installations and industrial installations are estimated to cost between $15 and $60 per square foot (District of Columbia Water and Sewer Authority, 2012). In the Old Town area of Alexandria, a value of $60 per square foot is recommended.

2.1.2 Permeable Pavement

Permeable pavement systems are infiltration systems in which stormwater runoff infiltrates through voids in the pavement surface into an underlying gravel base reservoir and to the ground. Some examples of permeable pavement systems include porous asphalt, porous concrete, modular perforated concrete blocks, interlocking concrete pavers, and cobble pavers. These systems are designed to treat the rainfall over the pavement surface area. Permeable pavements control runoff volume while also reducing pollutants and nutrients in the stormwater runoff.

In a 2012 technical memorandum produced by DC Water titled *Technical Memorandum No. 7: Green Infrastructure Screening Analysis for the Potomac River and Rock Creek* estimated permeable pavements to have a cost of approximately $30 per square foot. Porous asphalt tends to have a lowest unit cost and pervious pavers are typically the most expensive (District of Columbia Water and Sewer Authority, 2012). Select data from the 2012 report are summarized in Table 2-1. Due the challenges associated with the highly urbanized area of Old Town Alexandria, $30 per square foot is also recommended for the City's LTCPU planning.

Table 2-1
Unit Costs of Select Permeable Pavement Project

Type	Escalated Unit Cost	Unit	Source
Pervious Pavement	$15.55	SF	DC Water LTCP TM-3
Concrete Paving Blocks	$10.45	SF	LID Center
Pervious Concrete (includes base rock)	$14.02	SF	City of Portland
Concrete Paving Blocks (installed/no drain)	$20.20	SF	Fairfax County
Permeable Alley	$41.46	SF	LID Center - Lafayette
Permeable Pavers	$12.37	SF	CWP (Hathaway and Hunt)
Porous Pavement	$9.90	SF	US EPA
Permeable Pavers (no underdrain)	$16.53	SF	NC State

2.1.3 Rain Barrels

Rain barrels are water tanks that are used to collect and store rainwater from roofs that would otherwise be lost to runoff and diverted to storm drains and streams. The reduction of nutrients of this practice is equal to the runoff reduction rate. A rain barrel is a relatively simple and inexpensive practice; typical rain barrels have a volume of 55 gallons and can be placed under any residential gutter down spout.

The City currently has a rain barrel program in which City residents can purchase a rain barrel for their property for $65. For the purposes of cost estimating the cost for purchase and installation by the City will be $175 per rain barrel, which is based on retail rain barrel costs.

2.2 On-Site Underground Retention/Detention

On-site underground retention / detention systems capture and store stormwater runoff in pipes or other subsurface structures. The stormwater enters the system from a riser pipe connected to a catch basin or curb inlet. The collected stormwater eventually flows into a series of chambers or compartments where it is stored. The stored flows are eventually released back into the surface waters at a predesigned flow rate. This practice can attenuate the stormwater flows in the system and provide a relatively constant discharge flowrate.

In a 2012 technical memorandum produced by DC Water titled *Technical Memorandum No. 6: Green Infrastructure Technologies*, estimated that underground retention/detention costs range between $0.50 and $30 per gallon of rainwater stored. Retrofit projects will tend to be at the higher end of this range due to limiting working conditions during construction.(District of Columbia Water and Sewer Authority, 2012)

2.3 Vegetated Swales

Vegetated swales, or bioswales, are broad and shallow channels composed of a dense stand of vegetation covering the sides and the bottom of the channel. Swales are designed to trap particulate pollutants, promote infiltration and reduce the velocity of stormwater runoff. In general, swales are most effective in areas with low flow and smaller populations. They can be used in high density urban areas along roadways where space is limited and being used as a landscape feature.

In a 2012 technical memorandum produced by DC Water titled *Technical Memorandum No. 6: Green Infrastructure Technologies*, estimated that vegetated swales costs range between $20,000 and $30,000 per acre of impervious treated.(District of Columbia Water and Sewer Authority, 2012)

Section 3 Combined Flow

3.1 Inflow Reduction

Inflow reduction can be described as the practice to reduce the amount of storm water runoff that enters the combined sewer system (CSS). Technologies used to minimize inflow include: basement sump pump redirection, flow restriction and flow slipping, roof drain redirection, stormwater infiltration sumps, and stream diversion.

Some buildings tend to have sump pumps that deliver floodwater from basements into the CSS. Basement sump pump redirection involves redirecting this flow away from the CSS and to lawns, dry wells or drainfields, where the flow can permeate into the ground. Soil conditions such as porosity, slope and type need to be taken into account when implementing this strategy. Rebates are normally used to encourage homeowners to participate in basement sump pump redirection programs.

Flow restriction and flow slipping techniques employ roads and overland flow routes to temporarily store storm water on the surface or to convey water away from the CSS. Flow restriction is accomplished by limiting the rate at which surface runoff enters the CSS. Flow slipping is achieved by intentionally routing or slipping the entry of surface runoff into the CSS and allowing the runoff to travel through overland flow routes. Some examples of flow restriction and flow slipping devices include flow restricting orifice devices for catch basins and catch basin covers. Flow restricting orifice devices range from $800 to $1,900 per device (2014 dollars). Catch basin covers, which can be thought of as a steel plate cost at least $150 (U.S. Environmental Protection Agency, September 1999).

Stormwater infiltration sumps are underground structures designed to collect storm runoff and convey it into the surrounding soil. The system consists of a manhole chamber, which serves as a sedimentation basin, and an attached infiltration sump chamber. Once the flow in the manhole chamber reaches an overflow point, the infiltration sump chamber will begin to fill and eventually the perforations in this second chamber should allow the water to permeate outward into the ground. Costs are estimated to range from $3 to $12 per 1,000 gallons (2014 dollars) of inflow removed per year (U.S. Environmental Protection Agency, September 1999).

3.2 Regulator Overflow Facilities

Regulator overflow facilities for CSS areas are designed to control the amount of flow that enters an interceptor from the upstream system and provide an overflow point, the CSO, for flows that exceed the capacity of the interceptor. Regulators are generally built to intercept any wet-weather flow and can be configured to control CSO frequency and volume. These structures can be classified into two groups, static regulators or dynamic regulators. Static regulators refer to structures that have no moving parts and cannot be adjusted without manual changes or structural modifications. Examples of static regulators are weirs, restricted outlets, swirl concentrators and vortex valves. Dynamic regulators refer to structures that have a range of settings which allow varying volumes of flow to be intercepted and diverted in response to flow conditions. Some examples of dynamic regulators are inflatable dams, hydraulic gates, and float-controlled gates.

The cost of regulators depends on the design flow to be diverted, the type of regulator and special design considerations like having solids and floatable control features. Table 3-1 shows a list of CSO regulator projects and their corresponding cost. This table is based on construction projects for the City of Richmond, VA and Alexandria, VA. All costs are converted to 2014 costs.

Table 3-1
Costs of CSO Regulators for Selected Projects

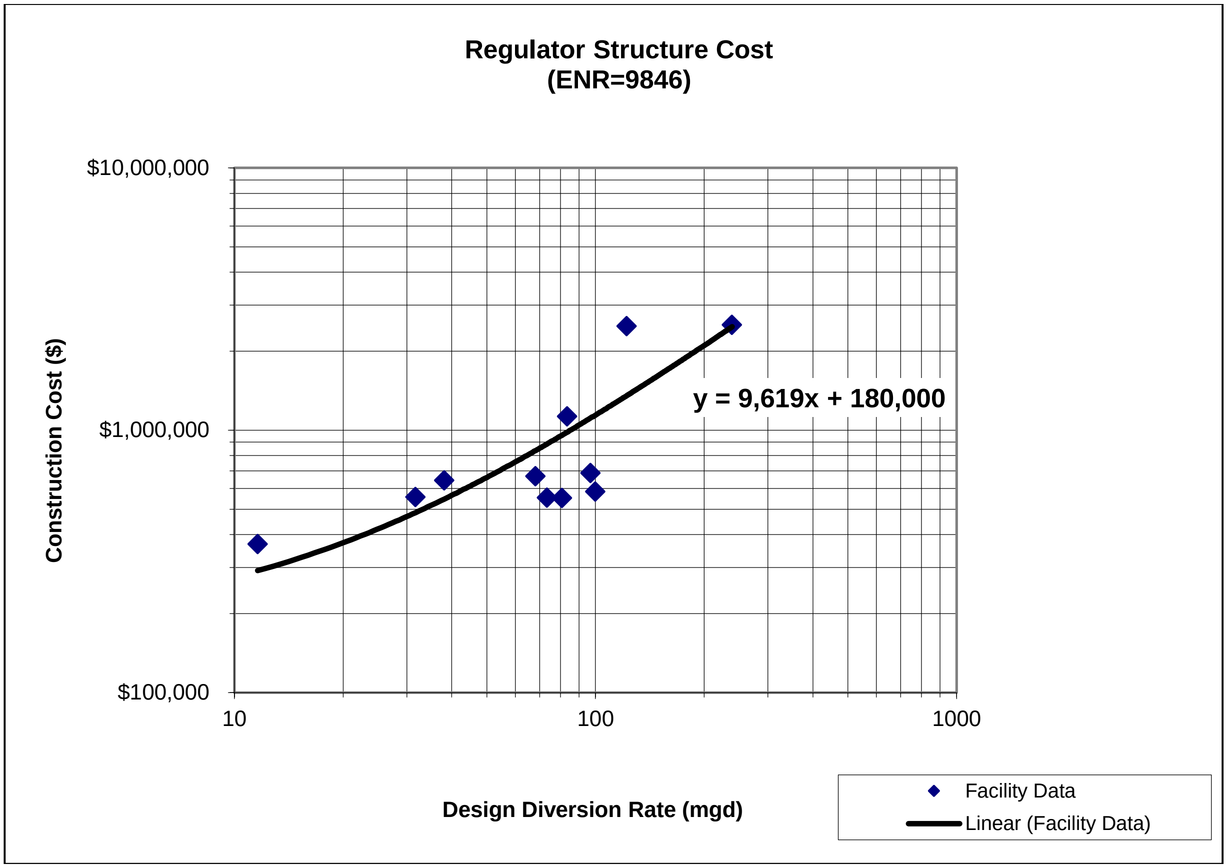
Diversion Structure	Design Diversion Flow (mgd)	Year of Construction	Construction Cost[1] ($)
Byrd Street	11.6	1996	$367,640
7th Street	32	1996	$555,095
Park Hydro	38	1996	$643,382
Reedy Creek	68	1995	$667,569
42nd Street	73	1995	$552,419
McCloy Regulator	81	2000	$551,302
Woodland Heights	83.5	1995	$1,127,382
Hampton Regulator	97	2000	$686,428
Gambles Hill	122	1996	$2,487,108
Canoe Run	239	1995	$2,515,791
King and West	90	2014	$583,186
[1]costs adjusted to 2014 costs			

Figure 3-1 shows a plot of the construction costs against the design diversion flow in a logarithmic scale, from where the following cost equation was obtained:

$$Cost\ of\ CSO\ Regulator = 9{,}473 \times Q(mgd) + 180{,}000$$

Ultimately the City's recent project for the King and West Diversion structure, which was bid and constructed in 2014, provides the best data point for the diversion structures associated with the LTCPU. As such, a unit cost of $600,000 is used for each diversion structure in the LTCPU.

Figure 3-1
Design Diversion Flow vs. 2014 Construction Cost for CSO Regulators



3.3 Retention Basins and Storage Tanks

Combined sewer overflow (CSO) retention basins, or storage tanks) are responsible for capturing and storing the excess combined sewer flow that would otherwise be bypassed to receiving waters. When flows are reduced and capacity becomes available at the treatment facility, the flows stored in retention basins will consequently be returned to the sewer system during dry weather periods. Retention basins can be built in-line or off-line. In-line retention basins are connected in series to the CSS and store excess flow when inlet flow exceeds outlet capacity while off-line retention basins are connected in parallel to the CSS and only receive flows during wet weather periods. Off-line retention basins are more costly than in-line retention basins since parallel lines need to be constructed and pumping facilities are also needed to pump the wastewater back into the sewers.

Table 3-2 shows a list of selected CSO retention basin projects and their corresponding cost. Costs associated with retention basins will significantly be influenced by the design criteria as seen by the wide range in construction and operations and maintenance (O&M) costs. This table was developed based on information presented in the *EPA Combined Sewer Overflow Technology Fact Sheet on Retention Basins*

(U.S. Environmental Protection Agency, September 1999). EPA developed a construction cost curve for retention basins (U.S. Environmental Protection Agency, September 1993). The equation of the curve is:

$$CSO\ Retention\ Basin\ Construction\ Cost = aV^{b}$$

Where: V is the storage volume in millions of gallons (MG)
a and b are constants which are unique to each line fit

Using the data in Table 3-2 to determine a and b, and converting all costs to 2014 costs, the estimated construction cost curve for CSO retention basins is:

$$CSO\ Retention\ Basin\ Construction\ Cost = 6.9671V^{0.7811}$$

The relationship between cost and design size can be seen in Figure 3-2.

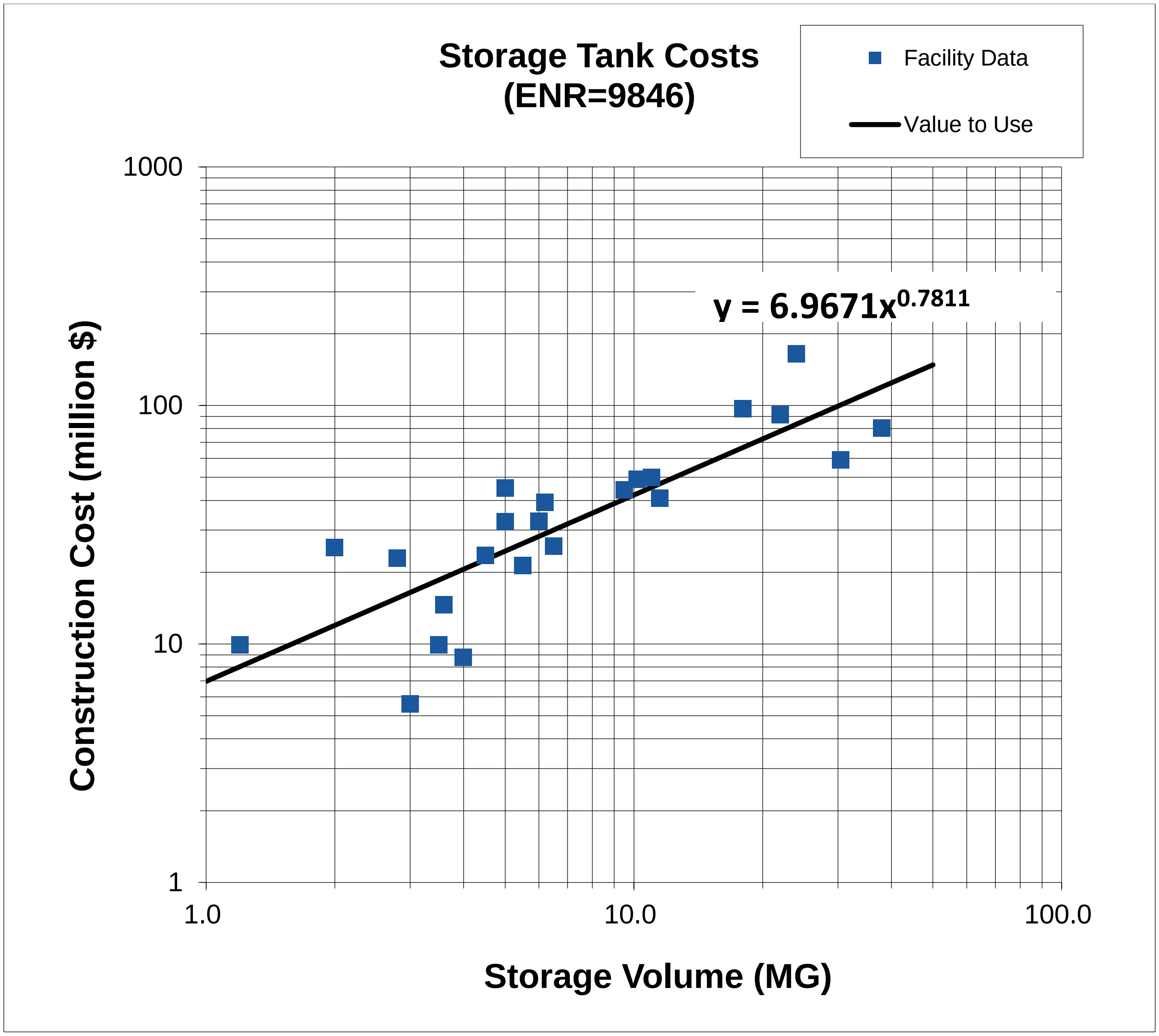
Table 3-2
Costs of Retention Basins for Selected Municipalities

Facility	Storage Volume (MG)	Escalated Construction Cost ($ in millions)	Escalated Unit Cost[1] ($M/MG)
Fitzhugh, Saginaw, MI	1.2	$9.90	$8.25
Seven Mile, Detroit	2.0	$25.35	$12.68
Salt/Frazer, Saginaw, MI	2.8	$22.86	$8.16
Seneca WWTP, MD	3.0	$5.58	$1.86
Chattanooga, TN	3.5	$9.88	$2.82
Webber, Saginaw, MI	3.6	$14.58	$4.05
Acacia Park, MI	4.5	$23.50	$5.22
Narragansett Bay, RI	5.0	$45.03	$9.01
Emerson, Saginaw, MI	5.0	$32.57	$6.51
Birmingham, MI	5.5	$21.30	$3.87
WSSC-Rock Creek	6.0	$32.68	$5.45
Sunnydale, SF, CA	6.2	$39.28	$6.34
14th St., Saginaw, MI	6.5	$25.68	$3.95
Weiss Street, Saginaw, MI	9.5	$44.24	$4.66
Bloomfield Village, MI	10.2	$48.85	$4.79
Edmund, Oakland, CA	11.0	$49.94	$4.54
Yosemite, SF, CA	11.5	$40.88	$3.55
Tournament Club, Detroit	22.0	$91.31	$4.15

Facility	Storage Volume (MG)	Escalated Construction Cost ($ in millions)	Escalated Unit Cost[1] ($M/MG)
North Shore, SF, CA	24.0	$164.05	$6.84
MARB, Grand Rapids, MI	30.5	$59.25	$1.94
Shockoe - Richmond, VA	38.0	$80.38	$2.12
Noman Cole EQ Tank, VA	4.0	$8.79	$2.20
AlexRenew NMF, VA	18.0	$96.86	$5.38

[1] costs adjusted to 2014 costs

Figure 3-2
Storage Tank Volume vs. 2014 Construction Costs



3.4 Pump Stations

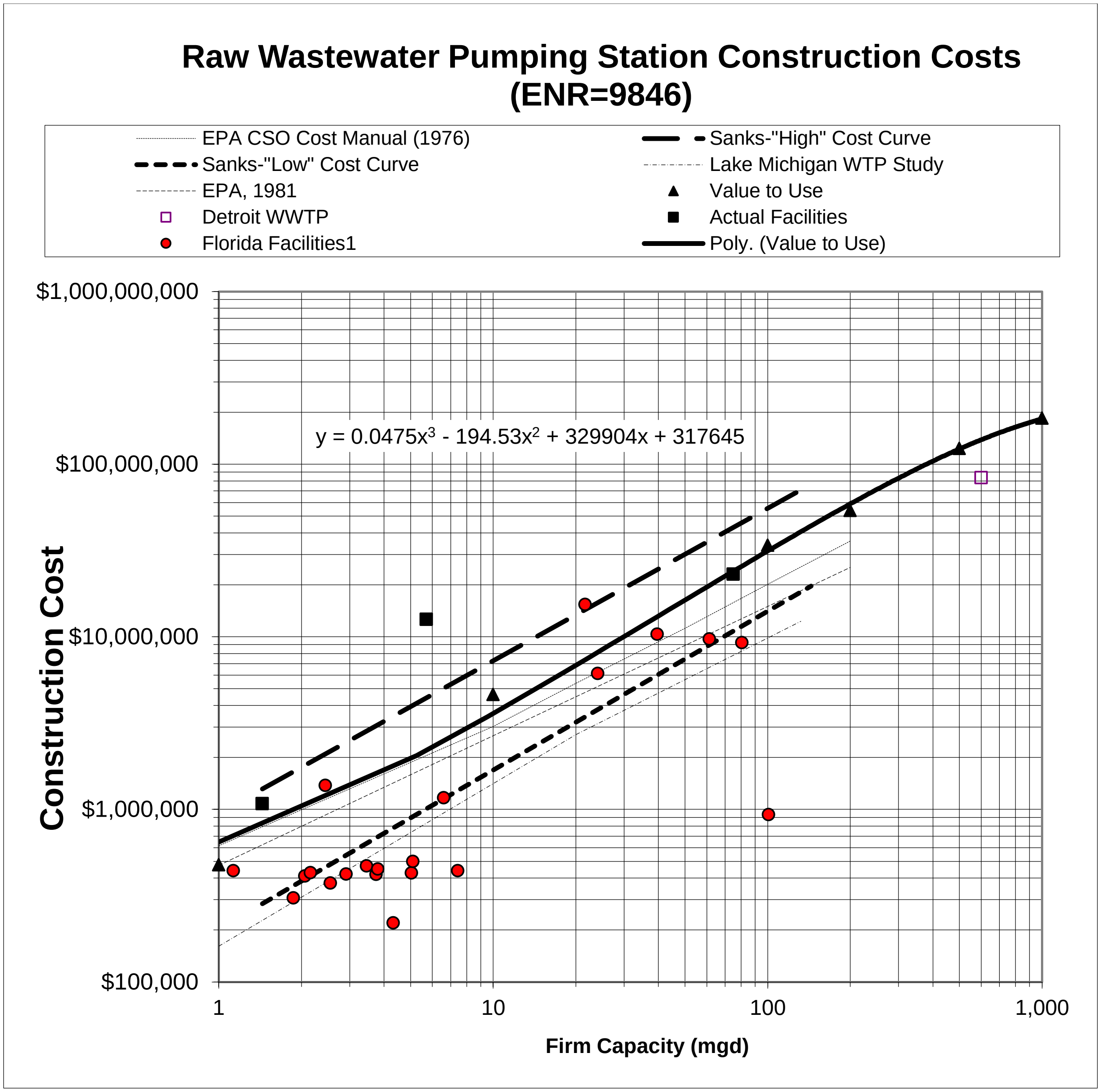
Cost data for pumping stations are based on the guidance in DC Water's Long Term Control Plan escalated to 2014. Costs were obtained from actual facilities, EPA cost curves, and other references and are summarized in Table 3-3.

Table 3-3
Costs of Pump Stations

Facility	Firm Capacity (MGD)	Escalated Construction Cost ($)	Escalated Unit Cost ($/MGD)
Cost Curves			
Sanks-"High" Cost Curve	1.44	$1,312,800	$911,667
Sanks-"High" Cost Curve	144	$76,580,000	$531,806
Sanks-"Low" Cost Curve	1.44	$284,440	$197,528
Sanks-"Low" Cost Curve	144	$19,692,000	$136,750
25th St. P.S. Tampa Fl	1	$85,571	$85,571
13th Street P.S. Tampa Fl	1	$161,199	$161,199
Lake Michigan WTP Study	20	$2,707,650	$135,383
Lake Michigan WTP Study	132	$12,307,500	$93,239
EPA CSO Cost Est Manual (1976)	1	$615,944	$615,944
EPA CSO Cost Est Manual (1976)	10	$3,022,834	$302,283
EPA CSO Cost Est Manual (1976)	20	$5,374,353	$268,718
EPA CSO Cost Est Manual (1976)	50	$11,196,576	$223,932
EPA CSO Cost Est Manual (1976)	100	$20,153,847	$201,538
EPA CSO Cost Est Manual (1976)	200	$35,922,361	$179,612
EPA 1981	1	$474,527	$474,527
EPA 1981	10	$2,668,459	$266,846
EPA 1981	20	$4,487,795	$224,390
EPA 1981	50	$8,922,531	$178,451
EPA 1981	100	$15,005,849	$150,058
EPA 1981	200	$25,236,729	$126,184
Actual Facilities			
Detroit WWTP	600	$83,718,299	$139,530
Poplar Point P.S.	75	$23,035,702	$307,143
Low Level P.S. adjacent to MPS	6	$12,612,506	$2,212,720
Site Runoff P.S.for B.P.	1	$1,079,774	$749,843
Florida Facilities[1]			
Dorchester	0.36	$211,576	$587,710
Newtown	0.94	$221,832	$237,000
Pump Station 3.17	2.45	$1,376,351	$562,235

Facility	Firm Capacity (MGD)	Escalated Construction Cost ($)	Escalated Unit Cost ($/MGD)
East Tampa	21.60	$15,397,647	$712,854
Hookers Point Plant	100.80	$931,982	$9,246
Hookers Point Plant	4.32	$219,768	$50,872
Apollo Beach	6.60	$1,168,242	$177,135
Paradise Fruit	1.13	$440,800	$389,950
55th Street	2.06	$410,348	$199,275
Wimauma	1.87	$306,719	$163,846
Ruskin	3.74	$420,870	$112,412
Buffalo Avenue	5.04	$428,411	$85,002
27th Street	2.16	$429,626	$198,901
Adalee Street	3.46	$469,993	$135,993
Fowler Avenue	3.80	$451,562	$118,782
Midlake Avenue	2.91	$421,982	$145,071
37th Street	7.42	$441,365	$59,457
Averill Avenue	5.10	$498,574	$97,806
Sheridan Road	2.55	$374,327	$146,864
San Carlos	39.60	$10,348,648	$261,329
Price Avenue	0.40	$219,250	$553,663
University	24.05	$6,121,265	$254,544
Sulphur Springs Telemetry	61.34	$9,710,971	$158,304
Ybor	80.64	$9,236,886	$114,545
Church Street	0.30	$155,154	$513,075
Beachway Drive	0.11	$462,688	$4,284,148

Figure 3-3
Pump Station Capacity vs. 2014 Construction Costs



The equation for construction cost as a function of flow rate (MGD) was escalated and is shown below.

$$\text{Pumping Station Cost} = 0.0475(MGD)^3 - 194(MGD)^2 + 329{,}990(MGD) + 317{,}645$$

3.5 Sewer Separation

Sewer separation refers to the practice of separating the combined pipe system into separate sewers for sanitary and stormwater flows. This practice can be accomplished by installing a new sanitary sewer and using the existing combined sewer as a storm sewer or vice versa. The sanitary flows will eventually be delivered to a treatment plant while the stormwater will be conveyed to a stormwater outfall that discharges into a receiving water body. This practice prevents that pathogenic bacteria and floatables in sanitary wastewater for being discharged to receiving waters.

Costs associated with sewer separation can vary considerably due to factors such as the current layout of the existing sewer system, nearby utilities that will have to be avoided, other infrastructure work, geotechnical conditions, maintenance of traffic, maintenance of service, and construction method used. Cost opinions for sewer separation vary widely should be based on site specific information. These generally represent the “low hanging fruit” and costs are expected to increase as the complexity of the projects increase.

Table 3-4 shows the capital costs of two separation projects of CSOs developed for the City of Alexandria and two separation projects for the Washington DC area. The costs vary highly due to particular characteristics of the projects, and the average cost per acre is $443,000. The two City of Alexandria projects demonstrate the large variability in the cost of separation projects. It should also be noted that the Payne and Fayette Sewer Separation was selected for design and construction based on its relatively low cost and complexity. It is expected the cost will increase dramatically as the complexity of separation projects increase.

Table 3-4
Capital Cost of CSO Separation Projects in Alexandria and Washington DC

Location	Project	Drainage Area (ac)	Escalated Construction Cost	Escalated Unit Cost ($/ac)
Alexandria, VA	Tanyard Ditch	11.5	$9,388,477	$816,389
Alexandria, VA	Payne and Fayette	7.41	$1,042,468	$140,684
Washington, DC	Anacostia CSO 006	13.56	$3,319,404	$244,794
Washington, DC	Rock Creek CSO 031, 037, 053 and 058	28.46	$13,212,452	$464,246
			Weighted Average	**$443,000**

3.6 Tunneling

An underground storage tunnel is one option for the LTCPU that will be evaluated. The information below will be used in developing preliminary costs for the tunnel alternatives.

3.6.1 Tunnel

Table 3-5 shows the unit cost for tunnels on a per linear foot basis in soil in various cities escalated to 2014 dollars.

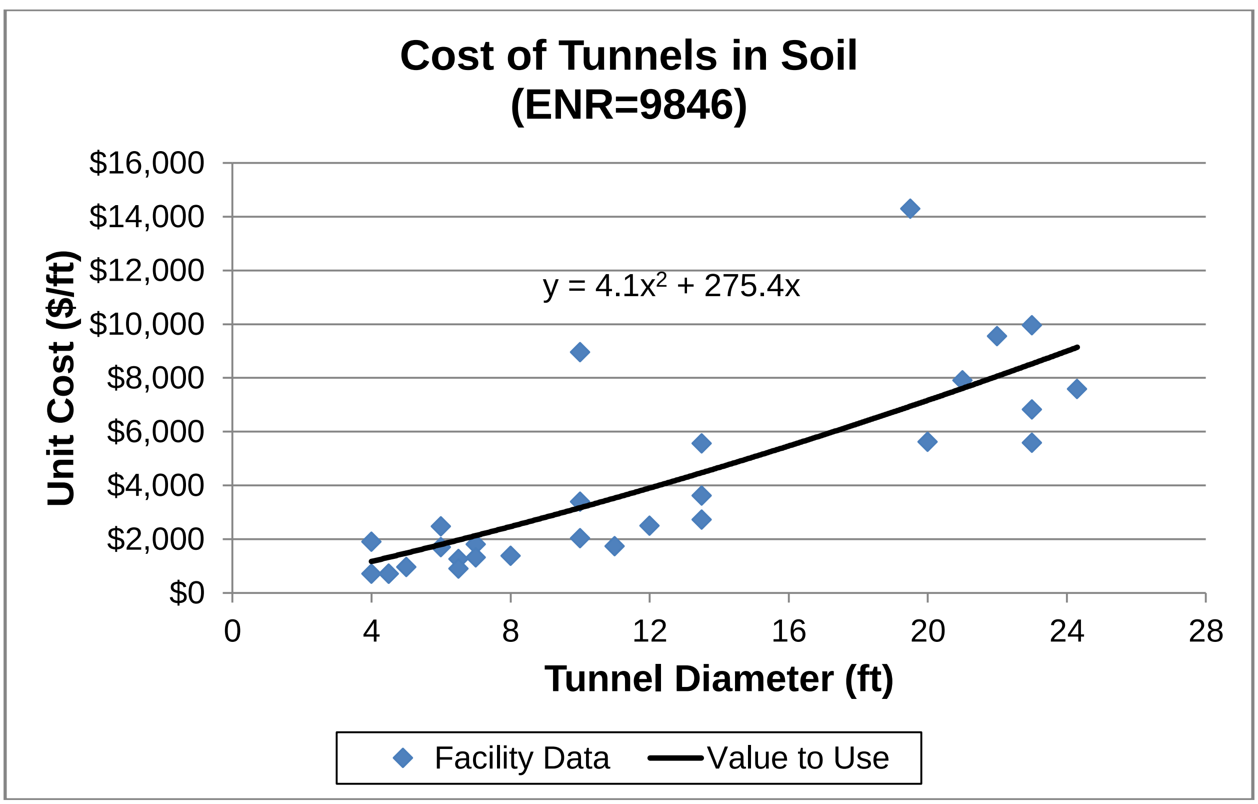
Table 3-5
Cost Data for Tunnels in Soil

Facility	Finished Diameter (feet)	Escalated Construction Cost ($/ft)
Recent Project Data		
DC Water		
First Street Tunnel - Division P (DC Water)	19.5	$14,297
Blue Plains Tunnel - Division A (DC Water)	23	$5,590
Anacostia River Tunnel - Division H (DC Water)	23	$6,829
Cleveland		
Dugway West Interceptor Relief Sewer (DWIRS) - average of six 4' tunnels	4	$1,902
Dugway West Interceptor Relief Sewer (DWIRS) - average of six 6' tunnels	6	$2,479
Westerly Tunnel	10	$8,954
Shoreline Tunnel	21	$7,907
Southerly Tunnel	23	$9,958
Los Angeles		
East Side LRT Gold Line Project	22	$9,549
Historical Project Data		
Birmingham, MI	4	$705
Birmingham, MI	4.5	$705
Down River, MI	4.5	$705
East Lansing, MI	5	$956
Birmingham, MI	6	$1,705
Birmingham, MI	6.5	$1,256
Down River, MI	6.5	$898
Birmingham, MI	7	$1,806
Down River, MI - average of three 7' tunnels	7	$1,319
PCI, MI - average of two 8' tunnels	8	$1,374
East Lansing, MI	10	$2,037
Southfield, MI	10	$3,392

Facility	Finished Diameter (feet)	Escalated Construction Cost ($/ft)
Birmingham, MI	11	$1,732
Chicago, IL	12	$2,495
PCI, MI	13.5	$5,561
Toledo, OH - average of two 13.5' tunnels	13.5	$3,615
Wyandotte, MI	13.5	$2,720
Cleveland	20	$5,624
Hartford, CT	24.3	$7,590

The unit costs in Table 3-5 were plotted to develop a cost curve that could be used for cost estimating. Figure 3-4 shows the cost curve for a tunnel in soil and the equation for a line of best fit in order to estimate costs for tunnel sizes that are not represented in the above table.

Figure 3-4
Unit Cost Curve for Tunnels in Soil



For a tunnel in soils the cost per linear foot of tunnel at various diameters can be estimated by the equation:

$$\mathit{Unit\ Cost\ per\ Linear\ Foot\ of\ Tunnel\ in\ Soils} = 4.1 * (\mathit{Diameter})^2 + 275.4 * \mathit{Diameter}$$

Available geotechnical information and the general site alignments were reviewed and specific unit costs were developed for tunnels sized between 6-ft and 12-ft. See Table 3-6. Estimates take into consideration experience from recent DC Water projects.

Table 3-6
Tunnel Unit Costs

Tunnel Diameter	Unit Cost ($/LF)
6-ft	$2,900
8-ft	$3,600
12-ft	$4,900

3.6.2 Drop Shafts

Drop shafts are required to convey the CSS flows from the CSS, down into the tunnel. For larger drop shafts there are three main components:

- Tangential inlets – these are approach channels that are designed to force the flow into a spiral pattern
- Dropshaft – this is the vertical drop shaft were the flow spirals around the walls of the drop shaft in order to allow air to escape up the center. This helps to prevent bulking of flow and to help dissipate energy.
- Deaeration chamber – this is located at the bottom of the drop shaft and allows are to escape the flow before it enters the tunnel.

Similar to the tunnels, available geotechnical information and the general site alignments were reviewed and specific unit costs were developed for drop shafts between 15-ft and 25-ft in diameter. See Table 3-7. Estimates take into consideration experience from similar shaft sizes and depths on DC Water projects.

Table 3-7
Drop Shaft Unit Costs

Drop Shaft Diameter	Unit Cost ($/VF)
15-ft	$26,000
20-ft	$32,000
25-ft	$37,000

Using the data from Table 3-7, the drop shaft costs are estimated by the following equation:

$$Unit\ Cost\ per\ Vertical\ Foot\ = 1{,}100\ x\ diameter + 10{,}000$$

Section 4 Land Costs

Some of the CSO alternatives may require the acquisition of private property by the City for the construction of the infrastructure. In order to estimate the cost of this land, available tax assessment data was gathered from the City's website for properties in the area of the existing outfalls and summarized in Table 4-1.

Table 4-1
Land Cost Basis

Address	Lot Size (SF)	Land Value	$/SF
1501 Duke St	18,244	$2,412,860	$132
1601 Duke St	4,280	$535,000	$125
100 Jones Point Dr	2,369,736	$178,698,793	$75
1202 S. Washington St	501,581	$18,686,873	$37
1199 S. Washington St.	558,579	$22,440,000	$40
724 S ST. Asaph St	46,618	$8,284,000	$178
915 S. Washington St	86,838	$4,900,000	$56
Total/Weighted Average	**3,585,876**	**$235,957,526**	**$66**

For projects in the area of CSO-002 a value of $75/sf is used. For projects in the area of CSO-003 and CSO-004, a value of $125/sf is used to account for the more urbanized environment. For projects that span all three outfalls (i.e. tunnels) a blended value of $100/sf is used. Cost for acquiring existing buildings is not anticipated or included.

Section 5 Operation and Maintenance Costs

Operation and maintenance (O & M) costs were estimated using the following bases:

- Wastewater Treatment Costs – cost are based on AlexRenew's current rate of $6.44 per 1,000 gallons.
- Labor – Labor requirements for the various CSO alternatives were estimated. Labor costs are based on an assumed loaded labor rate of $50 per hour.
- Maintenance - costs for facilities were taken as a percentage of the construction cost, using similar guidance provided in DC Water's Long Term Control Plan.
- Power – electricity costs were based on a unit cost of $0.08 per kWH based on available data from local wastewater plants in the Northern Virginia.
- Chemicals – chemical requirements were determined for each CSO control alternative based on the estimated operation of that facility. Unit chemical costs were estimated based on available data from local wastewater plants in the Northern Virginia.

Table 5-1
Maintenance Cost Basis

Item	Unit	Cost Basis (per year)
Maintenance		
Storage Tanks	% of construction cost	1.5%
Pump stations	% of construction cost	3.0%
Disinfection	% of construction cost	3.0%
Tunnels	% of construction cost	1.0%
Green Infrastructure	% of construction cost	5.0%
Power	KW-Hr	$0.08
Chemicals		
Sodium hypochlorite, 15% solution strength	Pound	$0.50
Sodium bisulfite, 38% solution strength, 1.3:1 $SO_2 : Cl_2$ treatment ratio	Pound	$2.80

Section 6 Net Present Worth Analysis

Project life-cycle costs combine capital and O&M costs to allow reasonable comparisons between alternatives with high capital costs and those with high O&M costs. The life-cycle cost is the project cost plus the present worth value of ongoing O&M costs over the expected lifetime of the project. A present worth factor is used to convert annual O&M costs to a present value:

$$P = A \times [(1 + i)^n - 1] / [i (1 + i)^n]$$

Where:

P = Present worth of O&M cost (2014 dollars)
A = Annual O&M cost (2014 dollars)
i = Discount Rate (annual percentage rate)
n = Period of Analysis (years)

The discount rate, expressed as an annual percentage, accounts for future price changes to convert O&M costs over the project lifespan to dollars in the same year used for capital cost estimating. For the City's LTCPU, a planning period of 20 years and a discount rate of 3 percent were selected as reasonable values for planning purpose.

Table 6-1
Present Worth Assumptions

Item	Description
Planning Period	20 years
Discount Rate	3%
Present Worth Factor	14.88

The Net Present Worth (NPW) incorporates both the capital cost and the present worth of the annual O&M.

Section 7 References

Disctrict of Columbia Water and Sewer Authority. (2012). *Technical Memorandum No. 7: Green Infrastructure Screening Analysis for the Potomac River and Rock Creek.* Washington DC: Greeley and Hansen.

District of Columbia Water and Sewer Authority. (2012). *Technical Memorandum No. 6: Green Infrastructure Technologies.* Washington, D.C.: DC Water.

Greeley and Hansen LLC. (July 2002). *District of Columbia Water and Sewer Authority Combined Sewer System Long Term Control Plan.* Washington, D.C.: Greeley and Hansen LLC. Retrieved from https://www.dcwater.com/workzones/projects/pdfs/ltcp/Complete%20LTCP%20For%20CD.pdf

U.S. Environmental Protection Agency. (September 1993). *Combined Sewer Overflow Control.* United States Environmental Protection Agency, Office of Research and Development. Washington, D.C.: Office of Research and Development. Retrieved from http://nepis.epa.gov/Adobe/PDF/30004MAO.pdf

U.S. Environmental Protection Agency. (September 1999). *Inflow Reduction.* United States Environmental Protection Agency, Office of Water. Washington, D.C.: Office of Water. Retrieved from http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_inflwred.pdf

U.S. Environmental Protection Agency. (September 1999). *Retention Basins.* United States Environmental Protection Agency, Office of Water. Washington, D.C.: Office of Water. Retrieved from http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_csoretba.pdf

U.S. Environmental Protection Agency. (September 1999). *Storm Water Wetlands.* United States Environmental Protection Agency, Office of Water. Washington, D.C.: Office of Water. Retrieved from http://water.epa.gov/scitech/wastetech/upload/2007_05_29_mtb_wetlands.pdf

U.S. Environmental Protection Agency. (September 1999). *Wet Detention Ponds.* United States Environmental Protection Agency, Office of Water. Washington, D.C.: Office of Water. Retrieved from http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_wetdtnpn.pdf

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